MODIFICATIONS OF THE KIRKCUDBRIGHT CAPACITOR BANK SYSTEM FOR ETC OPERATIONS*

Jud Hammon, Sherry Hitchcock, Doug Hopwood, S. K. Lam, Tom Tatman
Maxwell Physics International
2700 Merced St., San Leandro, CA 94577

Steven Gilbert, Peter Chapman, Grant Hainsworth, Heath Wardle
Defence Evaluation and Research Agency
Sevenoaks, Kent TN14 7BP
UNITED KINGDOM

Abstract

The 29-module, 32 MJ capacitor bank at the Defence Evaluation and Research Agency (DERA) Electromagetic Launch Facility, in Kirkcudbright, Scotland, is presently being modified to enhance its capabilities in driving Electro Thermal (ET) and Electro Thermal Chemical (ETC) gun loads. The primary changes are:

- Installation of equipment allowing capacitor banks to be connected in series pairs, for higher-voltage operation.
- Removable inserts for the module pulse-shaping inductors to reduce inductance by approximately a factor of two for some of the modules.
- A set of high-energy inductors and associated buswork to allow insertion of a range of additional inductances in series with some modules

The modifications will allow a wide range of pulse shapes and durations to be delivered to ETC gun loads.

This paper summarizes the designs for each of the modifications to the bank, along with predicted performance of the system.

I. INTRODUCTION

Maxwell Physics International is preparing for a modification of the DERA 32 MJ capacitor bank in Kirkcudbright, Scotland[1]. The capacitor bank is shown in Figure 1. The bank was originally designed to drive Electromagnetic (EM) guns. While the bank has considerable flexibility, including sequential firing of the 29 modules, and can drive a range of ET and ETC gun loads effectively, the bank has some important limitations in these modes. The 11 kV module voltage limits the ability to drive interesting higher-impedance loads and the lack of reverse-current blocking in the modules results in too much energy in the "tail" of the pulse.

The modification project follows from a study performed earlier for DERA[2] on the strengths and weaknesses of the bank as an ETC driver, and which identified possible modifications of the bank to improve its effectiveness as an ETC gun driver. The modifications allow a doubling of the effective bank voltage, introduce additional flexibility in pulse durations, and block reverse currents, improving efficiency and significantly reducing the late-time energy in the pulse.

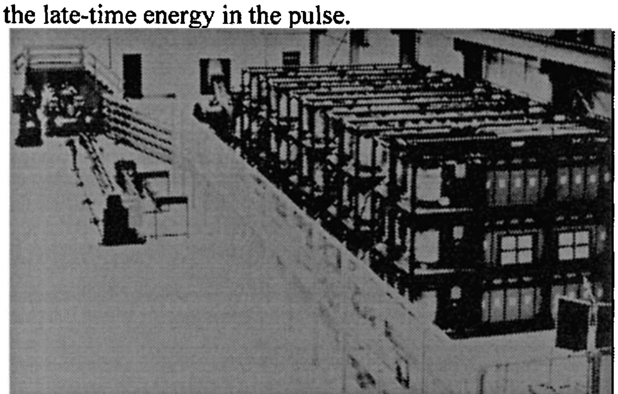

Figure 1. Kirkcudbright Electromagnetic Launch Facility Photo © DERA

II. INTERFACE/INTERCONNECTION MODULE

The primary feature of the modification is the ability to connect capacitor bank modules in series pairs, to better drive the higher-impedance and higher-voltage loads characteristic of high-energy ETC guns. The approach to this series connection of modules is shown schematically in Figure 2. Operation of similar modules in series-switched pairs was demonstrated in the 30 MJ capacitor bank at TZN, in Germany[3]. The TZN bank operates at charge voltages to 22 kV, for a 44 kV maximum output voltage.

In the Kirkcudbright modification, modules are connected, through the original output cables and coaxial (pipe) buswork, to an Interconnect/Interface module, where the series connection is made. Series blocking diodes and a selection of series inductors are also located in the Interface module. An isometric drawing of the Interface Module is shown in the two views of Figure 3.

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14. ABSTRACT

The 29-module, 32 MJ capacitor bank at the Defence Evaluation and Research Agency @ERA) Electromagetic Launch Facility, in Kirkcudbright, Scotland, is presently being modified to enhance its capabilities in driving Electra Thermal (ET) and Electra Thermal Chemical (ETC) gun loads. The primary changes are: - Installation of equipment allowing capacitor banks to be connected in series pairs, for higher-voltage operation. - Removable inserts for the module pulse-shaping inductors to reduce inductance by approximately a factor of two for some of the modules. - A set of high-energy inductors and associated buswork to allow insertion of a range of additional inductances in series with some modules The modifications will allow a wide range of pulse shapes and durations to be delivered to ETC gun loads. This paper summarizes the designs for each of the modifications to the bank, along with predicted performance of the system.

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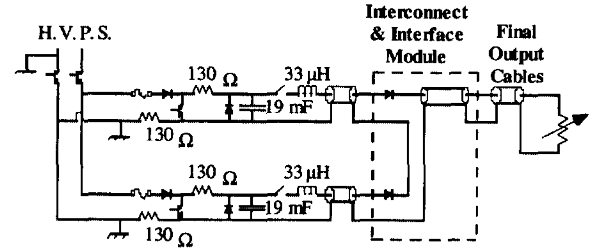

Figure 2. Simplified schematic of the series connection of a pair of capacitor bank modules.

This approach allows relatively quick and simple conversion between EM and ETC operations. EM guns, located at the upper left firing point in the photo of Figure 1, are connected directly to the existing output cables of the capacitor bank. Connections to ETC guns are through the interface module, which will be located to the right side of the EM gun firing point. ETC guns will be located at a second firing point outside the building through the door beyond and just to the left of the capacitor bank modules as viewed in Figure 1.

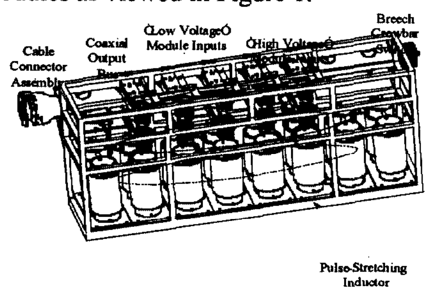

Figure 3a. Interface/Interconnect Module: Front View

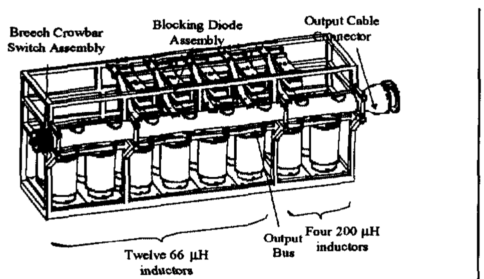

Figure 3b. Interface/Interconnect Module: Rear View

The interface module contains 10 cable connection points, each with a series blocking diode. The connection points are arranged in five pairs, with the "low-voltage" point above the "high-voltage" point. From the output side of the second blocking diode, connections can be made directly to the output bus or to one of the sixteen inductors located in the layer below the diode assemblies.

Both types of connections are shown in Figure 4 for a sample pulse-format. In this case, pulse-stretching inductors are used on the first two pulses (800 µH for pulse 1 and 400 µH for pulse 2). The remaining pulses use no added series inductance, and are connected directly to the output bus from the series diodes.

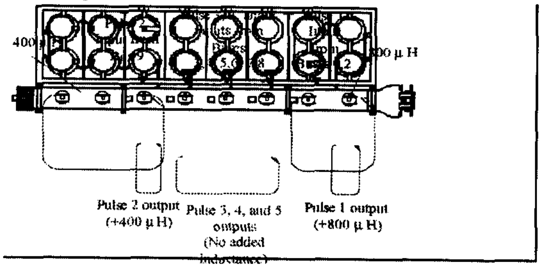

Figure 4. Inductor layer of the Interface Module, with connection scheme for a sample pulse format.

The combined output pulse shape, for one set of inter-pulse timings, is shown in Figure 5. Pulse shapes of each of the five pulses are shown in Figure 6. Clearly, modifying the timings of the individual pulses will result in different pulse shapes. Inserting different series inductance in any or all of the pulses, through the Interface Module, will further shape the pulse.

In this example, the capacitor bank modules for pulses 3, 4, and 5 are in the low-capacitance, low-inductance configuration. Converting one or more of the modules to the full-capacitance, full-inductance mode would further alter the pulse shape.

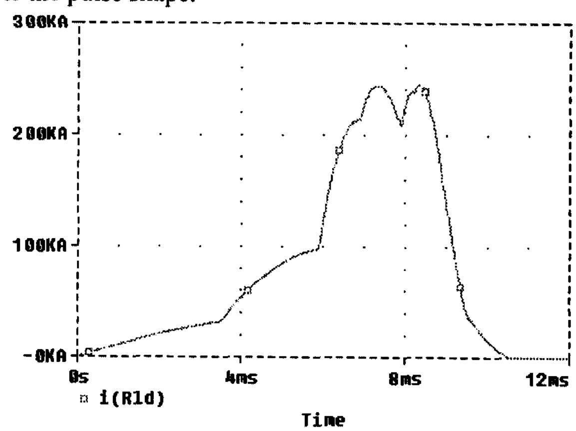

Figure 5. Sample pulse shape, with 800 µH added for pulse 1 and 400 µH for pulse 2.

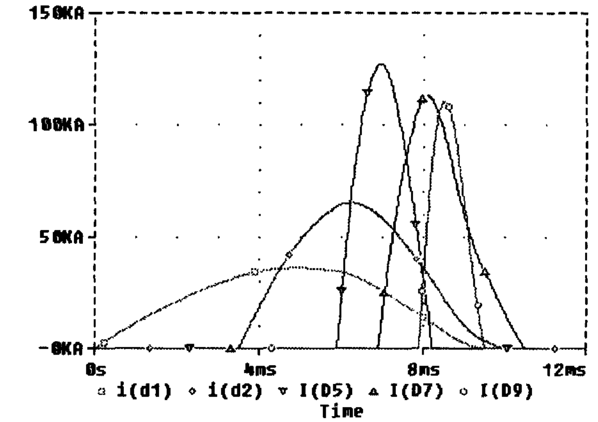

Figure 6. Individual pulses for the sample pulse shape of Figure 5.

III. CAPACITOR BANK MODULE MODIFICATIONS

To allow the modules to be connected in series pairs, the "charge/dump" panels on each module will be modified. The primary charges are to provide a high-energy resistor in both the "hot" and "return" legs of the charging panel and increase the voltage rating of the charging diode. The modified panels allow operation in either mode. No re-configuration is required to switch between modes.

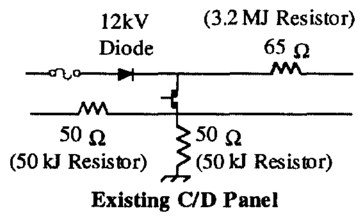

Figure 7. Charge-dump panel schematic prior to the ETC Modification.

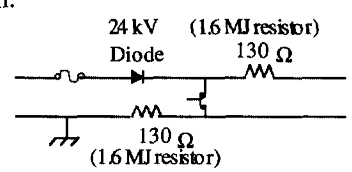

Figure 8. Charge-dump panel modified for operation in series pairs.

The high-voltage isolation of the "low" side of the capacitor bank module, is provided by a combination of insulating spacers and air gaps. In general, the "return" buswork is isolated from the grounded frame by at least 1 inch of air at all locations in the original design. The capacitor cans, however, are separated from the frame by only 1/8". This isolation, however, is provided by a rectangular tray with a lip approximately _" high all around. Pulse and dc tests at Maxwell Physics International indicate that the flashover voltage of a capacitor in these trays exceeds 30 kV, providing an adequate safety margin for the series switching.

To assure that the system is safe for series operation, the HV isolation of the "return" side of the "upper" modules will be tested with a low-energy 20 kV pulser prior to operation.

To further increase the flexibility of the system, inductor inserts are being supplied for six of the capacitor bank modules. The inserts can be installed inside the solenoidal pulse-shaping inductors in the modules, reducing the pulse shaping inductance from about 33 μH to about 17 μH. When this conversion is made, half of the capacitors in the affected module will be disconnected. This reduces the pulse length of the module to _ the original duration. Converted modules will always be used in series pairs, matching the capacitance of the pair, to prevent "ring-up" voltage gains that could damage the capacitors.

IV. BREECH CROWBAR SWITCH

A breech crowbar switch is included in the Interface Module, to protect against damage to the capacitor bank or the ETC gun breech in the event of certain faults. The switch will be triggered if the output current exceeds the pre-selected current limit within any one of three pre-selected timing windows.

The switch is a highly modified version of the Maxwell PI ST-300 spark gap switch used in each of the capacitor bank modules. In this switch, the trigger is provided by a triggatron-like plasma source. When set for a self-fire of approximately 28 kV, the switch still fires down to 1 kV on the switch, confirming its ability to serve as a crowbar switch.

If the switch is triggered early in the pulse on a full-energy shot, the switch can see a peak current over 600kA, and an action over 10^9 A^2-sec. At these levels, it is likely that the electrodes will be damaged. The switch has been designed to be simple to refurbish, and the electrodes are easily replaced.

V. SUMMARY

The modification of the Kirkcudbright capacitor bank system for improved ETC gun operations is in progress. Conversion of the bank is scheduled for fall, 1999.

VI. REFERENCES

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[3] J. Hammon, et. al., "A 30 MJ Modular 22kV/44kV Capacitor Bank," in the Proceedings of the Tenth International Pulsed Power Conference, 1995, page 261.